NF07279US

VIBRATION REDUCTION ZOOM LENS SYSTEM

The disclosures of the following priority application is herein incorporated by reference:

Japanese Patent Application No. 2002-381619 filed December 27, 2002.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a zoom lens for an SLR camera and a video camera and in particular to a zoom lens having vibration reduction correction.

Related Background Art

In order to reduce failure in shooting photograph by camera shake and the like, a zoom lens having vibration reduction correction has come to be used.

Conventional zoom lenses having vibration reduction correction are composed of two or more lens groups carry out vibration reduction correction by moving any lens group perpendicularly to the optical axis (for example, Japanese Patent Application Laid-Open Nos. 1-189621, 1-191112, 1-119113).

A zoom lens disclosed in Japanese Patent

Application Laid-Open No. 1-284823 carries out vibration reduction correction by moving a portion of a first lens group that is fixed upon zooming perpendicularly to the optical axis.

Moreover, zoom lenses disclosed in Japanese Patent Application Laid-Open Nos. 7-199124 and 10-111455 carry out vibration reduction correction by moving a third lens group perpendicularly to the optical axis.

Furthermore, a zoom lens disclosed in Japanese Patent Application Laid-Open No. 6-130330 carries out vibration reduction correction by moving a fourth lens group perpendicularly to the optical axis.

However, those conventional vibration reduction (VR) zoom lenses described above are not suitable for an SLR camera or a video camera or have inconvenience to become mechanically large and complicated.

SUMMARY OF THE INVENTION

The present invention is made in view of the aforementioned problems and has an object to provide a vibration reduction zoom lens system suitable for an SLR camera and a video camera having high optical performance and compactness by applying only a cemented lens as a vibration

reduction (VR) lens to make it compact and lightweight.

According to one aspect of the present invention, a vibration reduction zoom lens system includes, in order from an object, a first lens group having positive refractive power, a second lens group having negative refractive power, a third lens group having positive refractive power, a fourth lens group having negative refractive power, and a fifth lens group having positive refractive power. All distances between adjacent lens groups are changed upon zooming from a wide-angle end state to a telephoto end state. The third lens group includes a plurality of lenses including a cemented lens constructed by a negative lens cemented with a positive lens. Only the cemented lens is used as a vibration reduction lens shifting substantially perpendicularly to the optical axis for correcting camera shake. The following conditional expression (1) is satisfied:

$$0.6 < |f3A|/|f3| < 2.6 \qquad (1)$$

where f3A denotes the focal length of the vibration reduction lens of the third lens group, and f3 denotes the focal length of the third lens group.

In one preferred embodiment of the present invention, the following conditional expression (2) is preferably satisfied:

$$0.10 < |N3AN - N3AP| \quad (2)$$

where N3An denotes a refractive index of a medium of the negative lens of the vibration reduction lens at d-line (λ=587.6nm), and N3AP denotes a refractive index of a medium of the positive lens of the vibration reduction lens at d-line (λ=587.6nm).

In one preferred embodiment of the present invention, the following conditional expression (3) is preferably satisfied:

$$-0.50 < (R2+R1)/(R2-R1) < 0.50 \quad (3)$$

where R1 denotes a radius of curvature of the most object side lens surface of the vibration reduction lens, and R2 denotes a radius of curvature of the most image side lens surface of the vibration reduction lens.

In one preferred embodiment of the present invention, the following conditional expression (4) is preferably satisfied:

$$3.0 < FT \cdot f1/fT < 5.5 \quad (4)$$

where fT denotes the focal length of the vibration reduction zoom lens system in the telephoto end state, f1 denotes the focal length of the first lens group, and FT denotes the f-number of the vibration reduction zoom lens system in the telephoto end state.

In one preferred embodiment of the present

invention, the following conditional expression (5) is preferably satisfied:

$$0.40 < |f2|/fW < 0.80 \qquad (5)$$

where fW denotes the focal length of the vibration reduction zoom lens system in the wide-angle end state, and f2 denotes the focal length of the second lens group.

Other features and advantages according to the invention will be readily understood from the detailed description of the preferred embodiment in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram showing the lens arrangement of a vibration reduction zoom lens system according to Example 1 of the present invention.

Figs. 2A and 2B graphically show various aberrations of the vibration reduction zoom lens system according to Example 1 in a wide-angle end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 3A and 3B graphically show various aberrations of the vibration reduction zoom lens system according to Example 1 in a intermediate focal length state when the zoom lens is focused at

infinity, without and with vibration reduction correction, respectively.

Figs. 4A and 4B graphically show various aberrations of the vibration reduction zoom lens system according to Example 1 in a telephoto end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Fig. 5 is a diagram showing the lens arrangement of a vibration reduction zoom lens system according to Example 2 of the present invention.

Figs. 6A and 6B graphically show various aberrations of the vibration reduction zoom lens system according to Example 2 in the wide-angle end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 7A and 7B graphically show various aberrations of the vibration reduction zoom lens system according to Example 2 in the intermediate focal length state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 8A and 8B graphically show various aberrations of the vibration reduction zoom lens system according to Example 2 in the telephoto end

state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Fig. 9 is a diagram showing the lens arrangement of a vibration reduction zoom lens system according to Example 3 of the present invention.

Figs. 10A and 10B graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 in the wide-angle end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 11A and 11B graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 in the intermediate focal length state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 12A and 12B graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 in the telephoto end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention are going to be explained below with reference to accompanying drawings.

The vibration reduction zoom lens system is composed of, in order from an object, a first lens group G1 having positive refractive power, a second lens group G2 having negative refractive power, a third lens group G3 having positive refractive power, a fourth lens group G4 having negative refractive power, and a fifth lens group G5 having positive refractive power.

When the state of lens group positions varies from a wide-angle end state to a telephoto end state, a distance between the first lens group G1 and the second lens group G2 increases, a distance between the second lens group G2 and the third lens group G3 decreases, a distance between the third lens group G3 and the fourth lens group G4 increases, and a distance between the fourth lens group G4 and the fifth lens group G5 decreases.

The second lens group G2 is moved along the optical axis upon focusing.

It is generally preferable that a vibration reduction (VR) lens group that is shifted from the optical axis for vibration reduction correction is compact and lightweight having small shift amount

from the optical axis for vibration reduction correction. This is for making the holding and driving mechanism to be compact and for reducing power consumption. In order to suppress deterioration of optical performance upon vibration reduction correction as much as possible, it is preferable that the vibration reduction lens group is a lens group in which off-axis light rays pass through as near as possible to the optical axis through entire zoom range. Accordingly, it is preferable that a lens group locating in the vicinity of the aperture stop is adopted as the vibration reduction lens group.

In order to satisfy these conditions, in the present invention, the most suitable lens group for the vibration reduction lens group is the cemented lens L3A of the third lens group G3 locating in the vicinity of the aperture stop, having a small diameter and large refractive power, and capable of lowering the shifting amount from the optical axis.

In the present invention, the cemented lens L3A (hereinafter called "vibration reduction lens L3A") is preferably satisfies the following conditional expression (1):

$$0.6 < |f3A|/|f3| < 2.6 \qquad (1)$$

where f3A denotes the focal length of the vibration reduction lens L3A in the third lens group G3 and

f3 denotes the focal length of the third lens group G3.

Conditional expression (1) defines an appropriate range of power distribution between the vibration reduction lens L3A and the third lens group G3.

When the ratio $|f3A|/|f3|$ is equal to or exceeds the upper limit of conditional expression (1), the decentering amount of the vibration reduction lens L3A relative to the optical axis becomes large, so that the holding and driving mechanism becomes large and power consumption also becomes large.

On the other hand, when the ratio $|f3A|/|f3|$ is equal to or falls below the lower limit of conditional expression (1), Petzval sum of the vibration reduction lens L3A becomes large, so that optical performance upon vibration reduction deteriorates severely.

In order to bring the effect of the present invention into full play, it is preferable to set the upper limit of conditional expression (1) to 2.1 and the lower limit to 1.1.

In the present invention, the vibration reduction lens L3A is a cemented lens constructed by a negative lens L3AN cemented with a positive lens L3AP. This is because it is necessary to

suppress production of aberration at the vibration reduction lens L3A in order to maintain good optical performance upon vibration reduction. Accordingly, by applying the above-described cemented lens, production of aberrations including chromatic aberration upon vibration reduction can be reduced.

In the present invention, the negative lens L3AN and the positive lens L3AP composing the vibration reduction lens L3A preferably satisfy the following conditional expression (2):

$$0.10 < |N3AN-N3AP| \qquad (2)$$

where N3AN denotes the refractive index of the negative lens L3AN in the vibration reduction lens L3A at d-line (λ=587.6 nm) and N3AP denotes the refractive index of the positive lens L3AP in the vibration reduction lens L3A at d-line (λ=587.6 nm).

Conditional expression (2) defines an appropriate range of the difference of refractive index of the negative lens L3AN to that of the positive lens L3AP of the vibration reduction lens L3A at d-line (λ=587.6 nm).

When the value |N3AN-N3AP| is equal to or falls below the lower limit of conditional expression (2), although chromatic aberration can be corrected upon vibration reduction, in various aberrations other than chromatic aberration, degree

of freedom for correcting aberrations is small because difference of refractive index at d-line is small. Accordingly, optical performance deteriorates upon vibration reduction, so it is undesirable.

In the present invention, the following conditional expression (3) is preferably satisfied:

$$-0.50 < (R2+R1)/(R2-R1) < 0.50 \qquad (3):$$

where R1 denotes the radius of curvature of the most object side lens surface of the vibration reduction lens L3A and R2 denotes the radius of curvature of the most image side lens surface of the vibration reduction lens L3A.

Conditional expression (3) defines an appropriate range of the shape factor of the vibration reduction lens L3A. It is necessary that production of aberration of the vibration reduction lens while not performing vibration reduction correction should be as small as possible, and the deviation angle between on-axis incident light and on-axis exit light passing through the vibration reduction lens L3A varies as little as possible while performing vibration reduction correction. This is for suppressing the difference of production of aberration between while performing vibration reduction correction and while not performing vibration reduction correction in order

to reduce degradation of optical performance upon performing vibration reduction correction.

When the ratio $(R2+R1)/(R2-R1)$ is out of the scope of conditional expression (3), in other words equal to or exceeds the upper limit, or equal to or falls below the lower limit of conditional expression (3), the deviation angle between the incident light and the exit light of on axis light passing through the vibration reduction lens L3A varies largely upon vibration reduction correction. Accordingly, production of aberrations upon vibration reduction correction becomes large, so that high optical performance cannot be obtained upon vibration reduction correction.

In the present invention, the following conditional expression (4) is preferably satisfied:

$$3.0 < FT \cdot f1/fT < 5.5 \qquad (4):$$

where fT denotes the focal length of the vibration reduction zoom lens system in the telephoto end state, f1 denotes the focal length of the first lens group G1, and FT denotes the f-number of the vibration reduction zoom lens system in the telephoto end state.

Conditional expression (4) defines an appropriate range of the speed (apparent f-number) of the first lens group G1 in the telephoto end state.

When the value is equal to or exceeds the upper limit of conditional expression (4), the focal length of the first lens group G1 becomes extremely long. Accordingly, the moving amount of the first lens group G1 when zooming from the wide-angle end state to the telephoto end state becomes too long, so that compactness and lightweight cannot be accomplished.

On the other hand, when the value $FT \cdot f1/fT$ is equal to or falls below the lower limit of conditional expression (4), the focal length of the first lens group G1 becomes too short. Accordingly, variation in various aberrations upon zooming cannot be suppressed causing degradation of optical performance.

In the present invention, the following conditional expression (5) is preferably satisfied:

$$0.40 < |f2|/fW < 0.80 \quad (5)$$

where fW denotes the focal length of the vibration reduction zoom lens system in the wide-angle end state, and f2 denotes the focal length of the second lens group G2.

Conditional expression (5) defines an appropriate range of the ratio of the focal length of the second lens group G2 to that of the vibration reduction zoom lens system in the wide-angle end state.

When the ratio $|f2|/fW$ is equal to or exceeds the upper limit of conditional expression (5), it becomes difficult to secure a required sufficient back focal length in the wide-angle end state.

On the other hand, when the ratio $|f2|/fW$ is equal to or falls below the lower limit of conditional expression (5), the lens diameters of the third lens group G3, the fourth lens group G4, and the fifth lens group G5 locating to the image side of the second lens group G2 become large, so it becomes difficult to be compact and lightweight.

In the present invention, when carrying out vibration reduction correction, the method to rotate (tilt) the vibration reduction lens L3A around a position on the optical axis can be used.

In the present invention, only dioptric lens is used. However, it is needless to say that a diffractive optical element, a graded index lens, or the like may be used.

<Example 1>

Fig. 1 is a diagram showing the lens arrangement of a vibration reduction zoom lens system according to Example 1 of the present invention.

In a vibration reduction zoom lens system according to Example 1 of the present invention, the first lens group G1 is composed of, in order

from the object, a cemented lens constructed by a negative meniscus lens L11 having a convex surface facing to the object and a double convex positive lens L12, and a positive meniscus lens L13 having a convex surface facing to the object.

The second lens group G2 is composed of, in order from the object, a negative meniscus lens L21 having a convex surface facing to the object, a double concave negative lens L22, a double convex positive lens L23, and a negative meniscus lens L24 having a concave surface facing to the object.

The third lens group G3 is composed of, in order from the object, an aperture stop AS, a cemented lens L3A constructed by a negative meniscus lens L3AN and a double convex positive lens L3AP, and a positive meniscus lens L33 having a convex surface facing to the object.

The fourth lens group G4 is composed of, in order from the object, a positive meniscus lens L41 having a concave surface facing to the object, and a double concave negative lens L42.

The fifth lens group G5 is composed of, in order from the object, a double convex positive lens L51, a double convex positive lens L52, and a negative meniscus lens L53 having a concave surface facing to the object.

Various values according to Example 1 are shown in Table 1.

In Specifications, f denotes the focal length, FNO denotes f-number, 2W denotes the maximum value of the angle of view (unit: degree).

In Lens Data, the left most column is a surface number of a lens surface counted in order from the object, R denotes a radius of curvature of a lens surface, D denotes a distance to the adjacent lens surface, νd denotes Abbe number of the medium, Nd denotes a refractive index of the medium at d-line (λ=587.6nm). Bf denotes the back focal length. An aspherical surface is denoted by an asterisk (*) attached to the surface number.

In each Example, an aspherical surface is represented by the following expression:

$$x=cy^2/[1+(1-\kappa c^2y^2)^{1/2}]+C_4y^4+C_6y^6+C_8y^8+C_{10}y^{10}+C_{12}y^{12}$$

where y denotes the height from the optical axis, x denotes sag amount, c denotes a reference curvature (=1/R), κ denotes the conical coefficient, C_4 denotes the 4th order aspherical coefficient, C_6 denotes the 6th order aspherical coefficient, C_8 denotes the 8th order aspherical coefficient, C_{10} denotes the 10th order aspherical coefficient, C_{12} denotes the 12th order aspherical coefficient.

In Aspherical Data, "E-n" denotes "10^{-n}".

In Various Values upon vibration reduction

correction, the moving amounts of the vibration reduction lens and the image are positive when the movement is upper than the optical axis in each drawing showing the lens construction.

In each Example shown below, the same reference symbols as Example 1 are used.

In the tables for various values, "mm" is generally used for the unit of length such as the focal length, the radius of curvature, and the separation between optical surfaces. However, since an optical system proportionally enlarged or reduced its dimension can be obtained similar optical performance, the unit is not necessary to be limited to "mm" and any other suitable unit can be used. The explanation of reference symbols is the same in the other example.

Table 1

[Specification]

f=24.720 - 116.500 mm

FNO=3.601 - 5.627

2ω=83.58° - 20.29°

[Lens Data]

	r	d	ν	N(d)
1)	242.1205	1.9000	23.78	1.846660
2)	64.7339	7.3000	52.32	1.755000
3)	-1831.6851	0.1000		1.000000

4)	47.9741	4.8000	46.63	1.816000
5)	104.4072	d5		1.000000
*6)	78.9037	0.2000	38.09	1.553890
7)	78.9037	1.1500	42.72	1.834810
8)	13.0924	6.6000		1.000000
9)	-48.8888	0.9000	42.72	1.834810
10)	38.2686	0.1000		1.000000
11)	25.4358	5.3000	25.41	1.805182
12)	-27.7531	0.1600		1.000000
13)	-25.7724	0.9000	42.72	1.834810
14)	-9999.0000	d14		1.000000
15)	32.4485	0.8000	25.41	1.805182
16)	18.3178	4.6000	81.61	1.497000
17)	-31.0784	2.0000		1.000000
18)	27.6876	2.2000	70.24	1.487490
19)	229.3722	d19		1.000000
20)	-68.9111	2.5000	23.78	1.846660
21)	-20.4254	0.1000		1.000000
22)	-19.5549	0.8000	42.72	1.834810
23)	98.5615	d23		1.000000
24)	232.6091	6.2000	81.61	1.497000
25)	-24.6231	0.1000		1.000000
26)	60.7408	4.8000	70.24	1.487490
27)	-56.4358	4.5552		1.000000
28)	-23.4921	1.1000	23.78	1.846660
29)	-71.5684	Bf		1.000000

(Aspherical Data)

Surface Number 6

κ = -5.6933

C_4= 4.7040E-6

C_6= 2.1667E-9

C_8= -5.2564E-11

C_{10}= 1.0480E-13

C_{12}= 0.0000

[Variable Distance upon Zooming (focusing at infinity)]

f	24.720	70.000	116.500
d5	2.1726	22.1435	34.7219
d14	19.3969	6.5646	2.6583
d19	2.5585	15.4829	18.5624
d23	17.0465	4.1222	1.0426
Bf	38.0791	51.0035	54.0830

[Various Values upon VR Correction]

f	24.72mm	70mm	116.5mm
VR Lens Shift Amount (mm)	0.3	0.3	0.3
Image Shift (mm)	0.408	0.595	0.651

[Values for the Conditional Expressions]

N3AN= 1.805182

N3AP= 1.497000

R1 = 32.448

R2 = -31.078

fW = 24.720

fT = 116.500

f1 = 83.542

$f2 = -14.935$

$f3 = 26.381$

$f3A = 42.392$

$FT = 5.627$

(1) $|f3A|/|f3| = 1.607$

(2) $|N3AN-N3AP| = 0.308182$

(3) $(R2+R1)/(R2-R1) = -0.022$

(4) $FT \cdot f1/fT = 4.035$

(5) $|f2|/fW = 0.604$

Figs. 2, 3 and 4 graphically show various aberrations of the vibration reduction zoom lens system according to Example 1 at d-line (λ=587.6 nm).

Figs. 2A and 2B graphically show various aberrations of the vibration reduction zoom lens system according to Example 1 in a wide-angle end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 3A and 3B graphically show various aberrations of the vibration reduction zoom lens system according to Example 1 in an intermediate focal state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 4A and 4B graphically show various

aberrations of the vibration reduction zoom lens system according to Example 1 in a telephoto end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

In graphs for various aberrations, FNO denotes the f-number. W denotes a half angle of view. In the diagrams showing spherical aberration, FNO denotes f-number with respect to the maximum aperture. In the diagrams showing astigmatism and distortion, W denotes the maximum value of a half angle of view. In the diagrams showing coma, W denotes each half angle of view. In the diagrams showing astigmatism, S indicates a sagittal image plane and M indicates a meridional image plane. The explanation regarding aberration graphs is the same in the following Examples.

As is apparent from the respective graphs, the vibration reduction zoom lens system according to Example 1 shows superb optical performance as a result of good corrections to various aberrations in each focal length state (the wide-angle end state, the intermediate focal length state, and the telephoto end state) with and without vibration reduction correction.

<Example 2>

Fig. 5 is a diagram showing the lens

arrangement of a vibration reduction zoom lens system according to Example 2 of the present invention.

In a vibration reduction zoom lens system according to Example 2 of the present invention, the first lens group G1 is composed of, in order from the object, a cemented lens constructed by a negative meniscus lens L11 having a convex surface facing to the object and a positive meniscus lens L12 having a convex surface facing to the object, and a positive meniscus lens L13 having a convex surface facing to the object.

The second lens group G2 is composed of, in order from the object, a negative meniscus lens L21 having a convex surface facing to the object, a double concave negative lens L22, a double convex positive lens L23, and a negative meniscus lens L24 having a concave surface facing to the object.

The third lens group G3 is composed of, in order from the object, an aperture stop AS, a cemented lens L3A constructed by a negative meniscus lens L3AN and a double convex positive lens L3AP, and a positive meniscus lens L33 having a convex surface facing to the object.

The fourth lens group G4 is composed of, in order from the object, a positive meniscus lens L41

having a concave surface facing to the object, and a double concave negative lens L42.

The fifth lens group G5 is composed of, in order from the object, a double convex positive lens L51, a double convex positive lens L52, and a negative meniscus lens L53 having a concave surface facing to the object.

Various values according to Example 2 are shown in Table 2.

Table 2

[Specification]

f=24.720mm - 116.500 mm

FNO=3.604 - 5.903

2ω=85.16° - 20.24°

[Lens Data]

	r	d	ν	N(d)
1)	187.4154	1.9000	23.78	1.846660
2)	60.4398	7.1000	52.32	1.755000
3)	809.3772	0.1000		1.000000
4)	51.1110	4.9000	46.63	1.816000
5)	131.2200	d5		1.000000
*6)	122.6470	0.2000	38.09	1.553890
7)	122.6470	1.1500	42.72	1.834810
8)	13.7545	6.5000		1.000000
9)	-54.5024	0.9000	42.72	1.834810
10)	40.4384	0.1000		1.000000

11)	26.0771	5.3500	25.68	1.784720
12)	-26.6656	0.1300		1.000000
13)	-25.0155	0.9000	42.72	1.834810
14)	-9999.0000	d14		1.000000
15)	32.4485	0.8000	25.41	1.805182
16)	18.3178	4.6000	81.61	1.497000
17)	-31.0784	2.0000		1.000000
*18)	27.2189	2.2000	64.10	1.516800
19)	143.4442	d19		1.000000
20)	-69.6687	2.5000	23.78	1.846660
21)	-19.9954	0.1000		1.000000
22)	-19.1927	0.8000	42.72	1.834810
23)	95.9919	d23		1.000000
24)	172.0254	6.0000	81.61	1.497000
25)	-25.0691	0.1000		1.000000
26)	73.9596	4.9000	70.24	1.487490
27)	-45.8950	4.2246		1.000000
28)	-22.8090	1.1000	23.78	1.846660
29)	-68.9305	Bf		1.000000

(Aspherical Data)

Surface Number 6

κ = -6.2822

C_4= 4.4929E-6

C_6= 7.4142E-10

C_8= -4.2168E-11

C_{10}= 1.1193E-13

C_{12}= 7.0252E-18

Surface Number 18

$\kappa = 1.0063$

$C_4 = -9.6879E-7$

$C_6 = 2.1207E-8$

$C_8 = -3.8609E-10$

$C_{10} = 2.7728E-12$

$C_{12} = 0.0000$

[Variable Distance upon Zooming (focusing at infinity)]

f	24.720	70.000	116.500
d5	2.1554	21.8110	34.7047
d14	19.4169	6.5437	2.6783
d19	2.5228	15.6452	18.5267
d23	16.8651	3.7427	0.8612
Bf	38.5116	51.6341	54.5154

[Various Values upon VR Correction]

f	24.72mm	70mm	116.5mm
VR Lens Shift Amount (mm)	0.3	0.3	0.3
Image Shift (mm)	0.408	0.600	0.652

[Values for the Conditional Expressions]

N3AN= 1.805182

N3AP= 1.497000

R1 = 32.448

R2 = -31.078

fW = 24.720

fT = 116.500

f1 = 83.542

$f2 = -14.935$

$f3 = 26.381$

$f3A = 42.392$

$FT = 5.903$

(1) $|f3A|/|f3| = 1.607$

(2) $|N3AN-N3AP| = 0.308182$

(3) $(R2+R1)/(R2-R1) = -0.022$

(4) $FT \cdot f1/fT = 4.233$

(5) $|f2|/fW = 0.604$

Figs. 6, 7 and 8 graphically show various aberrations of the vibration reduction zoom lens system according to Example 2 at d-line (λ=587.6 nm).

Figs. 6A and 6B graphically show various aberrations of the vibration reduction zoom lens system according to Example 2 in a wide-angle end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 7A and 7B graphically show various aberrations of the vibration reduction zoom lens system according to Example 2 in an intermediate focal state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 8A and 8B graphically show various

aberrations of the vibration reduction zoom lens system according to Example 2 in a telephoto end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

As is apparent from the respective graphs, the vibration reduction zoom lens system according to Example 2 shows superb optical performance as a result of good corrections to various aberrations in each focal length state (the wide-angle end state, the intermediate focal length state, and the telephoto end state) with and without vibration reduction correction.

<Example 3>

Fig. 9 is a diagram showing the lens arrangement of a vibration reduction zoom lens system according to Example 3 of the present invention.

In a vibration reduction zoom lens system according to Example 3 of the present invention, the first lens group G1 is composed of, in order from the object, a cemented lens constructed by a negative meniscus lens L11 having a convex surface facing to the object and a positive meniscus lens L12 having a convex surface facing to the object, and a positive meniscus lens L13 having a convex surface facing to the object.

The second lens group G2 is composed of, in order from the object, a negative meniscus lens L21 having a convex surface facing to the object, a double concave negative lens L22, a double convex positive lens L23, and a negative meniscus lens L24 having a concave surface facing to the object.

The third lens group G3 is composed of, in order from the object, an aperture stop AS, a cemented lens L3A constructed by a negative meniscus lens L3AN having a convex surface facing to the object and a double convex positive lens L3AP, and a positive meniscus lens L33 having a convex surface facing to the object.

The fourth lens group G4 is composed of, in order from the object, a positive meniscus lens L41 having a concave surface facing to the object, and a double concave negative lens L42.

The fifth lens group G5 is composed of, in order from the object, a double convex positive lens L51, a double convex positive lens L52, and a negative meniscus lens L53 having a concave surface facing to the object.

Various values according to Example 3 are shown in Table 3.

Table 3

[Specification]

f=24.715mm - 116.180 mm

FNO=3.605 - 5.902

2ω=84.27° - 20.30°

[Lens Data]

	r	d	ν	N(d)
1)	216.4404	1.9000	23.78	1.846660
2)	64.1890	7.0000	52.32	1.755000
3)	41868.0830	0.1000		1.000000
4)	49.2996	4.8500	46.58	1.804000
5)	114.2131	d5		1.000000
*6)	96.1218	0.0400	38.09	1.553890
7)	85.6443	1.3500	42.72	1.834810
8)	13.3745	6.5500		1.000000
9)	-50.0350	0.9000	42.72	1.834810
10)	39.7947	0.1000		1.000000
11)	25.5984	5.5000	25.68	1.784720
12)	-28.1577	0.1100		1.000000
13)	-26.6982	0.9000	42.72	1.834810
14)	-10125.2810	d14		1.000000
15)	32.5433	0.8000	25.43	1.805180
16)	18.4480	4.7000	82.52	1.497820
17)	-32.0248	0.5000		1.000000
*18)	27.2447	3.0000	63.98	1.513419
19)	137.0245	d19		1.000000
20)	-74.9109	2.2500	23.78	1.846660
21)	-19.8416	0.0600		1.000000
22)	-19.1953	0.8000	42.72	1.834810
23)	84.8898	d23		1.000000

24)	124.4234	6.4500	82.52	1.497820
25)	-25.2886	0.1000		1.000000
26)	76.9570	4.7000	70.41	1.487490
27)	-51.0732	4.3000		1.000000
28)	-22.8139	1.1000	23.78	1.846660
29)	-66.6924	Bf		1.000000

(Aspherical Data)

Surface Number 6

$\kappa = -2.9054$

$C_4 = 4.5547E-6$

$C_6 = -4.3828E-9$

$C_8 = -3.8574E-11$

$C_{10} = 7.1398E-14$

$C_{12} = 1.2504E-16$

Surface Number 18

$\kappa = 0.9780$

$C_4 = -1.1742E-6$

$C_6 = 1.8701E-8$

$C_8 = -3.8781E-10$

$C_{10} = 2.7920E-12$

$C_{12} = -3.9268E-15$

[Variable Distance upon Zooming (focusing at infinity)]

f	24.715	70.000	116.180
d5	2.1645	22.0508	34.6978
d14	19.9929	7.1483	3.2832
d19	2.9356	15.9340	18.9269

d23	16.9818	3.9834	0.9905
Bf	38.2859	51.2842	54.2772

[Various Values upon VR Correction]

f	24.715mm	70mm	116.18mm
VR Lens Shift Amount (mm)	0.3	0.3	0.3
Image Shift (mm)	0.408	0.599	0.654

[Values for the Conditional Expressions]

N3AN= 1.805180

N3AP= 1.497820

R1 = 32.543

R2 = -32.025

fW = 24.715

fT = 116.180

f1 = 83.611

f2 = -14.935

f3 = 26.381

f3A= 43.039

FT = 5.902

(1) $|f3A|/|f3|$ = 1.631

(2) $|N3AN-N3AP|$ = 0.307360

(3) $(R2+R1)/(R2-R1)$ = -0.008

(4) $FT \cdot f1/fT$ = 4.248

(5) $|f2|/fW$ = 0.604

Figs. 10, 11 and 12 graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 at d-line (λ=587.6

nm).

Figs. 10A and 10B graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 in a wide-angle end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 11A and 11B graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 in an intermediate focal state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

Figs. 12A and 12B graphically show various aberrations of the vibration reduction zoom lens system according to Example 3 in a telephoto end state when the zoom lens is focused at infinity, without and with vibration reduction correction, respectively.

As is apparent from the respective graphs, the vibration reduction zoom lens system according to Example 3 shows superb optical performance as a result of good corrections to various aberrations in each focal length state (the wide-angle end state, the intermediate focal length state, and the telephoto end state) with and without vibration reduction correction.

As described above, the present invention makes it possible to provide a vibration reduction zoom lens system having high optical performance and compactness suitable for an SLR camera, a video camera, and the like.

Additional advantages and modification will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, and representative devices shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.